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Performance Analysis of an OFDM system using Channel Coding Techniques

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) has gained increased interest due to its robustness against multi-path interference and high spectrum efficiency. OFDM is a suitable candidate for high data rate transmission with forward error correction (FEC) methods over wireless channels. In this paper, the system throughput of a working OFDM system has been enhanced by channel coding technique like Reed Solomon code& Turbo Code. Forward Error Correcting codes are a new class of codes that can achieve exceptional error performance and energy efficiency at low signal-to-noise ratio.

The simulation is made with the development of Models in the SIMULINK & computer program written in MATLAB source code on the random data under additive white Gaussian noise (AWGN) channel. The simulation results of estimated Bit error rate (BER) show that the implementation of RS code with ½ -rated under QPSK modulation technique is highly effective to combat inherent interference in the communication system**.**For decoding of Turbo code, MAP decoding algorithm is used. In case of Turbo code BER performance is substantially improved by increasing number of iterations used in the decoding process.

General Terms

Channel Coding, Channel, decoding Algorithms, Modulation Technique etc.

Keywords

OFDM System, Channel Coding Techniques, Reed Solomon Code, Turbo Code , Bit Error Rate (BER), And Additive White Gaussian Noise (AWGN)

1. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a Multi-Carrier Modulation technique in which a single high rate data-stream is divided into multiple low rate data-streams and is modulated using sub-carriers which are orthogonal to each other. Some of the main advantages of OFDM are its multi-path delay spread tolerance and efficient spectral usage by allowing overlapping in the frequency domain. OFDM is symbol based, and can be thought of as a large number of low bit rate carriers transmitting in parallel. All these carriers transmitted using synchronized time and frequency, forming a single block of spectrum. This is to ensure that the orthogonal nature of the structure is maintained.

However, in the present study, an effort has been made merely to concatenate the various channel encoding codes to improve the reliable reception performance of an OFDM wireless communication system under different digital modulation schemes such as QPSK, 32-QAM, 64-QAM. In almost all applications of multi-carrier modulation, satisfactory performance cannot be achieved without the addition of some form of channel coding. In wireless systems subjected to fading, extremely high signal-to-noise ratios are required to achieve reasonable error probability. In addition, interference from other wireless channels is frequently severe.If channel coding is applied, the performance of OFDM is expected to be significantly improved through time diversity of channel coding as well as through inherent frequency diversity of the OFDM [1][2].

2. OFDM SYSTEM

In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-carriers are transmitted in parallel. These carriers divide the available transmission bandwidth. The separation of the sub-carriers is such that there is a very compact spectral utilization. OFDM is a subset of frequency division multiplexing in which a single channel utilizes multiple sub-carriers on adjacent frequencies [2].

In addition the sub-carriers in an The OFDM technique was first employed for broadcasting applications of audio and video signals such DAB (digital audio broadcasting) or DVB (digital video broadcasting).

Orthogonality of carriers is a necessary condition for the proper functioning of an OFDM system. Two functions f(x) and g(x) are said to be orthogonal in the period [a, b] if

$$\int_a^b f(x)g*(x)dx = 0 \ldots\ldots\ldots\ldots\ldots.(1)$$

Physically, if f(x) and g(x) are signals, then the LHS of (1) is a measure of how much common energy the spectra of these two signals have. In the case of OFDM, carriers are sinusoidal. Consider two sinusoidal functions $e^{j2\pi mft}$ and $e^{j2\pi nft}$ Then,

$$\frac{1}{T}\int e^{j2\pi mft} e^{-j2\pi nft} dt = \begin{cases} 0 & m \neq n \\ 1 & m = n \end{cases} \ldots\ldots\ldots.(2)$$

Where, T = 1/f.

Equation 2 shows that all harmonics of a sinusoid of frequency f are orthogonal to each other. This property is used in the generation of orthogonal carriers for OFDM signals.

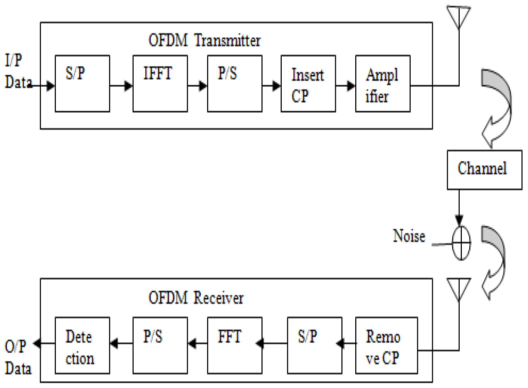

Figure 1: OFDM System

3. CHANNEL CODING

Channel coding refers to the class of signal transformations designed to improve communications performance by enabling the transmitted signals to better withstand the effects of various channel impairments, such as noise, interference, and fading.

FEC is accomplished by adding redundancy to the transmitted information using a predetermined algorithm. Each redundant bit is invariably a complex function of many original information bits. The original information may or may not appear in the encoded output; codes that include the unmodified input in the output are systematic, while those that do not are non systematic. If Channel coding is applied; the performance of OFDM is expected to be significantly improved through time diversity of channel coding as well as through inherent frequency diversity of the OFDM. In a multipath fading channel, if the data loss in a sub carrier channel occurs due to deep fade, it can be recovered from the coded data in alternative sub carrier channels which may not suffer from the same level of fade distortion.

3.1 Reed Solomon Code

RS codes are symbol error correcting codes, rather than bit error correcting, and each symbol is typically chosen from elements of extension fields, say, GF(2^m). The corresponding (n, k, t) regular RS code designed over GF (2^m) has a codeword composed of $n = 2^m - 1$ symbols, of which k symbols represent information. Using hard decision decoding, this RS code can correct symbol errors up to $t = n\text{-}k /2$ symbols.

Reed-Solomon codes are non binary cyclic codes with symbols made up of m-bit sequences, where m is any positive integer having a value greater than 2. R-S (n, k) codes on m-bit symbols exist for all n and k

for which $0 < k < n < 2^m + 2$ (1)

Where k is the number of data symbols being encoded, and n is the total number of code symbols in the encoded block. For the most conventional R-S (n, k) code,

$(n, k) = (2^m - 1, 2^m - 1 - 2t)$ (2)

Where t is the symbol-error correcting capability of the code, and $n - k = 2t$ is the number of parity symbols. An extended R-S code can be made up with $n = 2^m$ or $n = 2^m + 1$, but not any further.

One can say that the decoder has n - k redundant symbols to “spend,” which is twice the amount of correctable errors. For each error, one redundant symbol is used to locate the error, and another redundant symbol is used to find its correct value. Reed-Solomon codes are block-based error correcting codes with a wide range of applications in digital communications and storage[8].

Reed-Solomon codes are used to correct errors in many systems including, Storage devices,Wireless or mobile communications (including cellular telephones, microwave links, etc)Satellite communications, Digital television / DVB, High-speed modems such as ADSL.

REED SOLOMON ENCODER / DECODER TECHNICAL SPECIFICATIONS [8]:

- Symbol Length (m) =3 to 24
- No of input Symbols to encoder=k symbols
- No of encoded symbols of encoder=n symbols
- Error detecting capability (d) = n-k
- Error correcting capability (t) = (n-k)/2

3.2 Turbo Code

In the turbo decoding procedure, the decoding is iterated until the final decision on data is made. To meet the given Performance level, the number of iterations heavily depends on channel propagation conditions such as fading and shadowing. Of course, for low power consumption is desirable through the smaller number of iterations. To reduce the power consumption, the number of iterations should be reduced by some technique. For example, if we have some Information about channel state, we can adaptively change the number of iterations according to the channel conditions. However, to get the channel state information, channel estimation mechanism (or algorithm) is required, which leads to addition of another complexity to the system. To avoid this, a simpler method is required. One example for this is to employ CRC (cyclic redundancy check) to get the information about the changes of channel Conditions from the data bits of consecutive iteration processes.

Due to the use of soft-output Viterbi algorithm or MAP Algorithm, the size of the encoder registers, and hence theConstraint length of the component codes is severely limited since the decoding complexity measured by the number ofTrellis states exponentially increases [4].

4. SIMULATION

4.1 Simulation Model

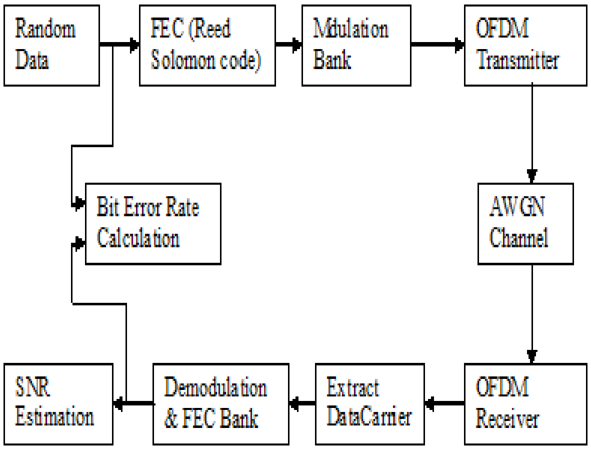

Figure 2: SIMULINK Simulation Model

4.2 Algorithm of Simulation [1]:

1. Generate the information bits randomly.

2. Encode the information bits using a Reed Solomon Encoder with the specified generator matrix & code rate.

3. Use QPSK or different QAM modulation to convert the binary bits, 0 and 1, into complex Signals (before these modulation use zero padding)

4. Performed serial to parallel conversion.

5. Use IFFT to generate OFDM signals, zero padding is being done before IFFT.

6. Use parallel to serial converter to transmit signal Serially.

7. Introduce noise to simulate channel errors. We assume that the signals are transmitted over an AWGN channel. The noise is modelled as a Gaussian random Variablewith zero mean and variance σ^2. The Variance of the clamour is obtained as

$$\sigma 2 = 1/\ (2^* \ Eb/No)$$

Thus the received signal at the decoder is:

$$X' = noisy\ (X)$$

8. At the receiver side, perform reverse operations to Decode the received sequence.

9. Count the number of erroneous bits by comparing the Decoded bit sequence with the original one.

9. Calculate the BER and plot it.

5. SIMULATION RESULTS

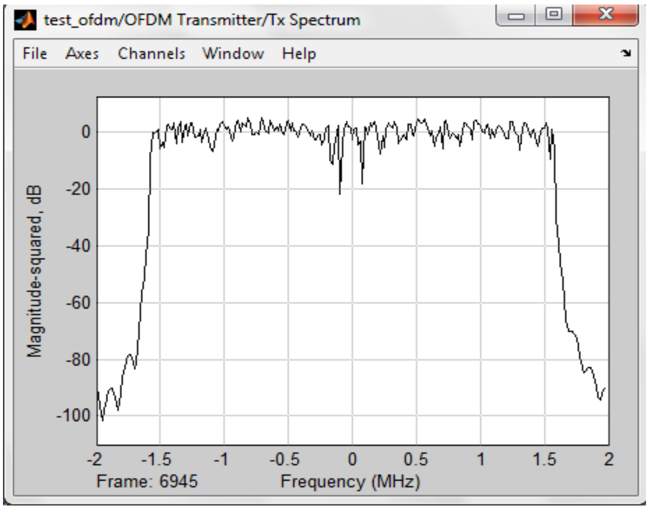

Figure 3: OFDM Signal

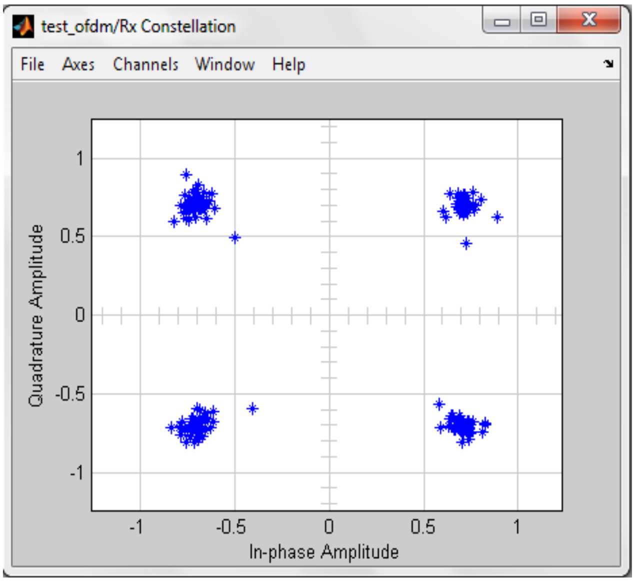

Figure 4: QPSK Constellation

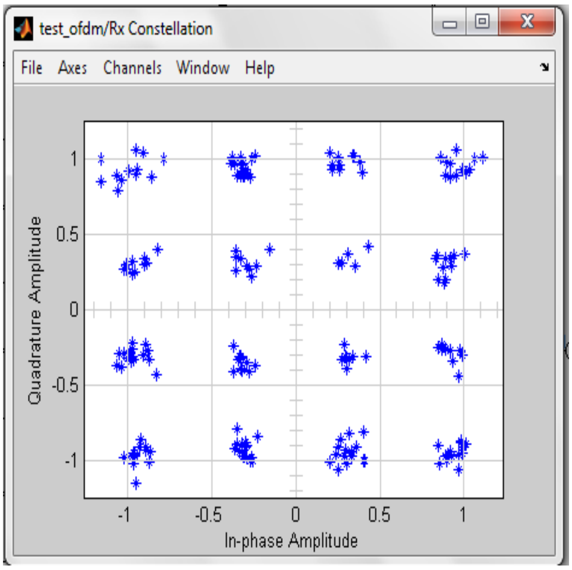

Figure 5: 16 QAM Constellations

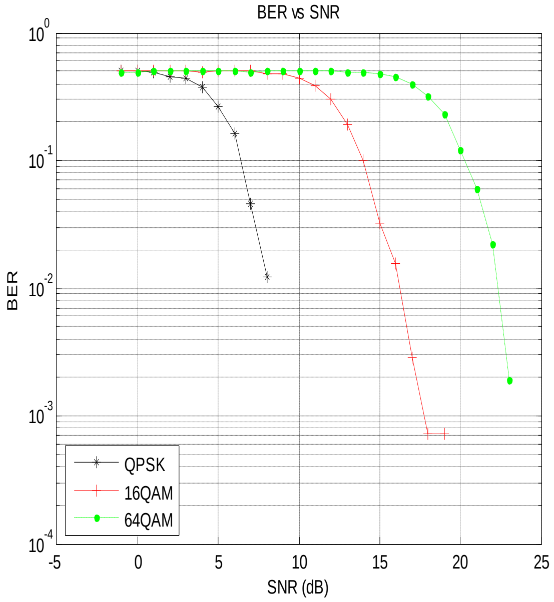

Figure 6: Performance Of OFDM System Using Reed SolomonCode (Code rate ½)

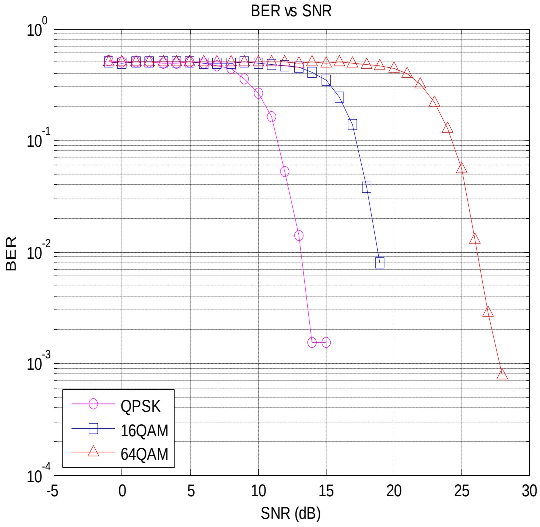

Figure 7: Performance of OFDM System Using Reed SolomonCode (Code rate3/4)

Table 1: Comparison of SNR for different code rate of Reed Solomon code under Modulation Technique

RS Code Rate	SNR for BER 10^{-2} (QPSK)	SNR for BER 10^{-2} (16QAM)	SNR for BER 10^{-2} 64QAM)
1/2	~ 8 dB	~ 16.5 dB	~ 22dB
3/4	~ 13 dB	~ 18.5 dB	~ 23 dB

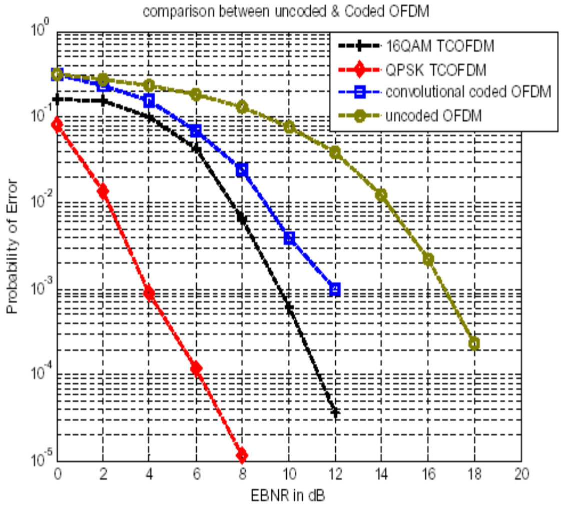

Figure 8: Different coded and uncoded OFDM system analysis overAWGN channel[1]

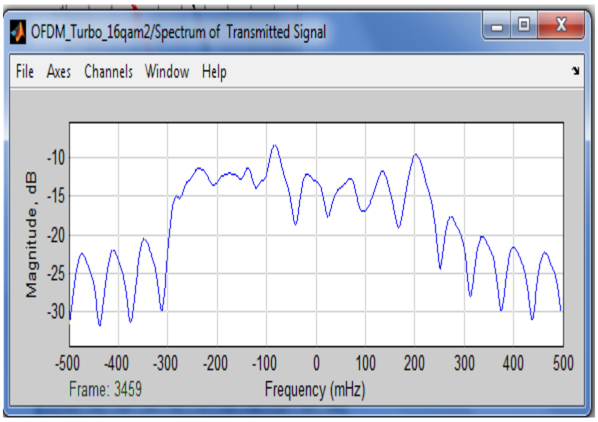

Figure 9: Transmitted OFDM Signal using Turbo Code

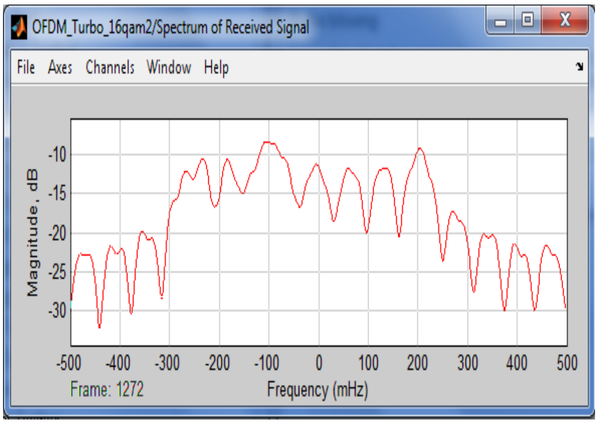

Figure 10: Received OFDM Signal using Turbo Code

6. CONCLUSION

First developing an OFDM system model then try to improve the performance by applying forward error correcting codes to our uncoded system.The implementation of interleaved Reed Solomon code with ¾ -rated Convolution code under QPSK modulation technique provides satisfactory result among the concatenated FEC channel coding schemes. In case of Turbo code BER performance is substantially improved by increasing number of iterations used in the decoding process. Turbo code performance is severely limited at low SNR due to error propagation in the iterative decoding.

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